



Exploration Systems Development Briefing to the NASA Advisory Council

Status of ESD, Orion, SLS, and GSDO

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23 July 2012





- **ESD Integration and Schedule**
- **Level 1 Requirements Modifications**
- **Status: Orion, SLS, GSDO**
- **Verification and Validation Approach**
- **Summary**

FY12 Significant Events - Upcoming



June 2012

*	Orion	P	LM sign contract (clean up) definitization
28	Orion	H	Crew Module (CM) structure shipped to Kennedy Space Center (KSC) to initiate Assembly, Integration and Production (AI&P) in the Operations and Checkout (O&C) Building

July 2012

1	GSDO	O	DOD Commitment of Recovery Assets (EFT-1)
11	GSDO	R	System Requirements Review/System Definition Review Kick-Off
15	SLS	P	Booster Proposals Due
27	Orion	R	MPCV Internal Program Re-Synchronization (KDP-B planning)
30	SLS	P	Advanced Booster Engineering Demonstration & Risk Reduction NRA Proposal(s) Selection

August 2012

1	Orion	P	EFT-1 Heat Shield Installation
3	SLS	P	Advanced Development NASA Research Announcement (NRA) SO Decision
10	SLS	P	Engine Proposal Due
15	SLS	P	Stages PPM Approved
30	GSDO	R	System Requirements Review/System Definition Review (SRR/SDR) Board

September 2012

11	GSDO	O	MPPF Construction Start
28	GSDO	R	SRB Retrieval Ships Fully Transferred to T&R

October 2012

15	MPCV	R	KDP-B APMC
11	GSDO	R	KDP-B Complete

FY13 Significant Events - Planned



Quarter 1

ESD	R	Cross-program System Design Review
GSDO	R	KDP-B Complete
Orion	P	EFT-1 Crew Module and Service Module Mate
Orion	R	KDP-B APMC
SLS	P	*Advanced Development NRA Contract Award
SLS	P	**Advanced Booster Engineering Demonstration & Risk Reduction NRA Awarded
SLS	P	Booster UCA Definitized
SLS	P	Engine UCA Definitized

Quarter 2

SLS	*	Stages UCA Definitized
SLS	P	Interim Cryo-Propulsion Stage Contract Award
Orion	T	Ground Test Article Water Basin Testing at Langley

Quarter 3

SLS	R	Preliminary Design Review (PDR)
SLS	T	Booster Qualitative Motor Test #1

ESD Program Integration Accomplishments



ESD Control Board

- A Hazard Acceptance Matrix was approved by the for inclusion in the S&MA Plan.
- Orion-MPCV tactical requirements and HAT MPCV delta-V requirements were discussed for a possible L2 Mission based on the Waypoint Analysis.

DPMC

- Updates to the ESD Level-1 requirements providing tactical relief in seven areas were approved.

ESD

- ESD conducted a Face-to-Face discussion in Huntsville for a Cross-Program Systems Definition Review
- CSI held its Monthly Technical-Cost-Schedule Review
- In support of the GAO Quick Look audit, ESD briefed GAO on June 20,2012, on the integration activities underway in ESD.
- A Technical Coordination Meeting was held to disposition comments to the ESD Risk Management Plan.
- ESD conducted a session on Continuous Risk Management and the use of the Active Risk Manager
- ESD conducted a monthly review of the ESD Division risks, and will recommend closure of the LOC/LOM risk.

Resources

- FY 2012 funds distribution up to 99%
- Submitted third Agency Operating Plan

June 2012 Requirement Revision Summary



Reqt #	Requirement	Baseline (FROM)	June 2012 Revision(TO)	Reason for Change
R-1	Earth Entry Velocity.	11,500 m/s	Tactical- 11,200 m/s Strategic- 11,500 m/s	Align with Tactical capability needs
R-2	Crew Size.	2, 3, 4, with a demonstrable evolution path to 6	Rationale revised with more detail for the 2,3,4 and 6 crew sizes and to address the omission of 0 crew from the requirement	Clarification
R-3	MPCV Delta-V.	1500 m/s	Tactical- 1340 m/s Strategic- TBD	Align with planned capability.
R-4	MPCV Active Mission Duration.	Provide habitable environment for 21 days (crew of 4)	<i>No Changes</i>	<i>No Changes</i>
R-5	MPCV Control Mass.	30,257 kg	Tactical- 33,340 kg Strategic- TBD	Align with actual maximum mass for architecture closure of HLO and L2 capability
R-6	Nominal Post-Landing Crew Recovery.	Recover crew within 2 hours from nominal site	"GSDO shall" to "Architecture shall" to align with allocation to MPCV and GSDO	Align with correct allocations of requirements to Programs
R-7	Post-Landing Crew Survival.	Provide for crew survival for 24 hours for contingencies	"MPCV shall" to "Architecture shall" to align with allocation to MPCV and GSDO	Align with correct allocations of requirements to Programs
R-8	Cargo Return Mass.	Return pressurized cargo 100 kg (crew of 4) 250 kg (crew of 2-3)	This requirement is not applicable at the Tactical capability level.	Not required for Tactical capability

June 2012 Requirement Revision Summary



Req# #	Requirement	Baseline (FROM)	June 2012 Revision(TO)	Reason for Change
R-9	Service Module.	SM configurable as a standalone element	This requirement is not applicable at the Tactical capability level.	Not required for tactical capability
R-10	Human Rating.	Architecture shall be human rated	<i>No Changes</i>	<i>No Changes</i>
R-11	SLS Lift Capability.	105 metric tons	Tactical- 70 metric tons Strategic- 105 metric tons, with a demonstrable evolution path to 130 metric tons	Align with planned capability..
R-12	Payload Dimensions.	7.5 m dia and 18 m barrel length, evolvable to 9.1 m dia and 30 m barrel length	Block 1a/2- 1291 m ³ and 7.5 m dia Block 2- 1672 m ³ and 9.1 m dia	Resolution of stack integration problem.
R-13	Orbital Insertion Accuracy.	Orbital insertion accuracies to an injection point of -87 x 241 km (-47x130 nmi) @ 28.5 degrees	Resolved TBRs associated with the insertion accuracies	TBR resolution.
R-14	Alternate means of delivering Crew to/from ISS.	Capable of delivering crew to/from ISS in the event other vehicles are unable	<i>No Changes</i>	<i>No Changes</i>
R-15	Launch Rate.	1-3 launches in a year	Tactical- 1 launch/ 2 years Strategic- up to 3 launches/year Specify 120 day spacing	Clarification and alignment with PPBE assumptions.

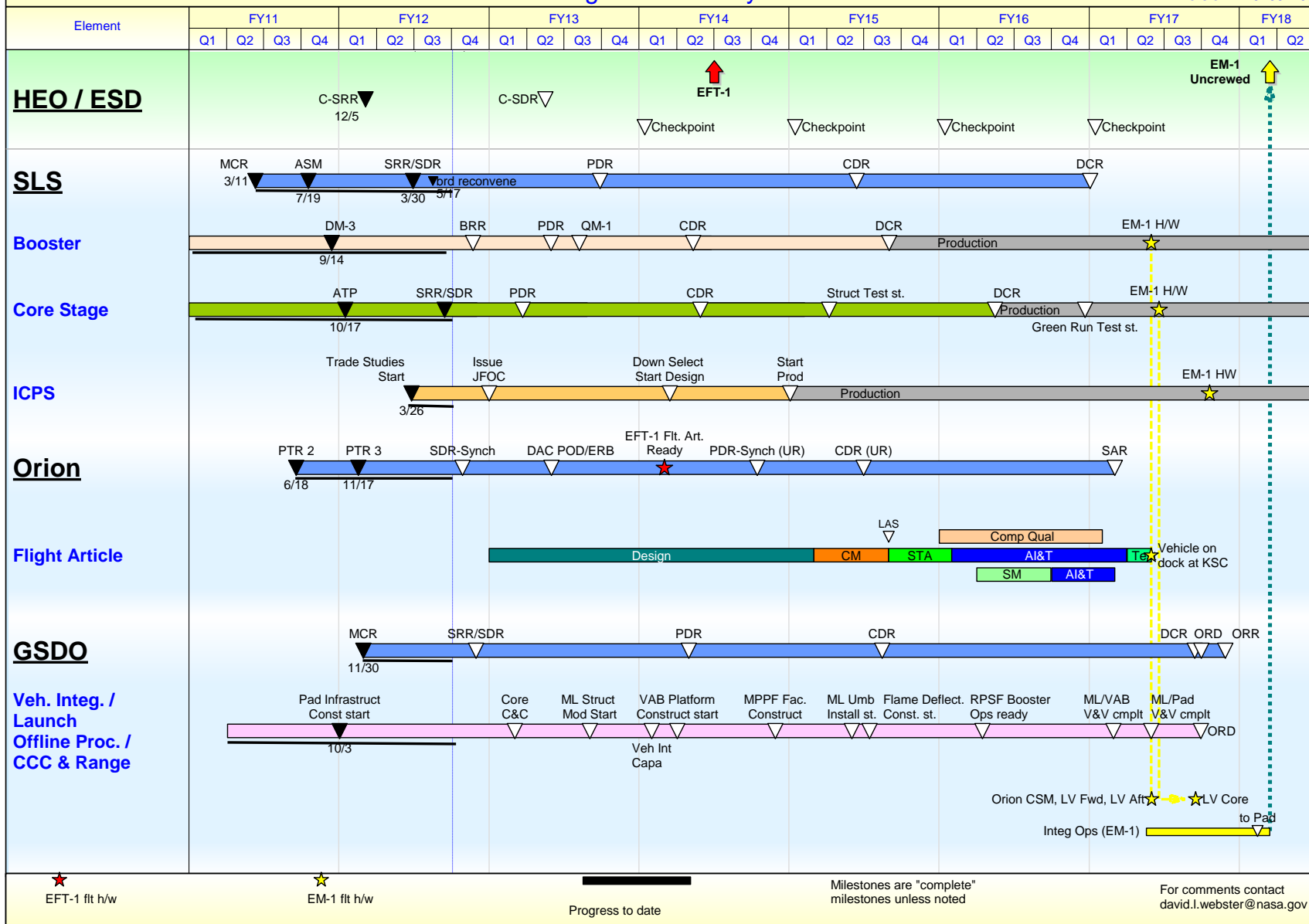
June 2012 Requirement Revision Summary



Req# #	Requirement	Baseline (FROM)	June 2012 Revision (TO)	Reason for Change
R-16	Loss Of Crew.	Mission aggregate and Launch/ Entry LOC values for a variety of mission types	Requirement and rationale revised to cover only EM-2 LOC values MPCV Launch & Ascent- 1:1400 SLS Launch & Ascent- 1:550 MPCV EDL & Recovery- 1:650	Closure of TBRs
R-17	LOC Improvement.	Commit resources toward LOC improvement	<i>Deleted</i>	Covered by existing NPRs
R-18	Loss Of Mission.	Mission aggregate and Ascent, In-space, and Return LOM values for a variety of mission types	<i>Deleted</i>	Carry as TPM against DRM. Actual LOM dependent upon actual mission.
R-19	Launch Availability.	95% likelihood of launching within 30 days	<i>Deleted</i>	Carry as TPM to influence design. No strong justification for requirement given projected manifest
R-20	Audio and Motion Imagery.	Provide audio and motion imagery to the ground	Clarified to include engineering eval data, in-cabin and external real-time, near real-time and streaming	Clarification
R-21	Cost Requirement.	Programs shall not exceed TBD cost values	<i>Deleted</i>	Carry as TPM to influence program planning. Requirement not appropriate prior to confirmation

ESD Tri-Program Summary Schedule

version: 120703 R0





Orion MPCV Overview



Program

- ESA SM DAC1 Complete/Phase 0 Safety TIM/Program Mgrs Briefing
- EFT-1 CM Arrival Ceremony @ KSC

Avionics

- Delivered CM Flight GPS Antenna
- Delivered FSW 7.1 for verification
- Shipped VPU EDU #1 to ITL

Crew / Service Module

- CM: Completed Closeout weld; Shipped CM to KSC
- Backshell Tile Production 14.5% complete
- Completed heatshield carrier structure layup
- SM: Continued composite and metallic structure manufacturing

CM Final Weld & Delivery



➤ Completed CM5 Closeout EFT1



➤ CM Deliver to KSC

- **Closeout Weld**
 - Load Barrel / Cone Str 5542 - Complete
 - OFT 1 Weld Activity - Complete
 - OFT1 NDE - Complete
- **Shipping Preparations**
 - Priming - Complete
 - Strain Gage Installation – Complete
 - Work Doc for Pack and Ship - Complete
 - Shakedown & Pre-ship Preparations – Complete
 - Load CM into CMTF - Complete



CM Shipped!

Arrived at KSC on 6/28/2012

Orion Test Campaign

Reducing Risk while Maturing Design



GTA Acoustic Testing



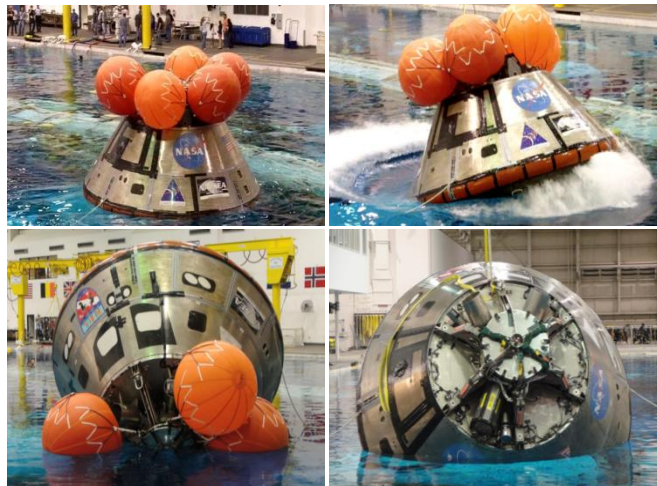
Telemetry Data Flow Test



Crew Safety and Training



Water Drop Tests at LaRC



Crew Module Up-righting System Test



Pad Abort 1



Parachute Tests: PTV 1

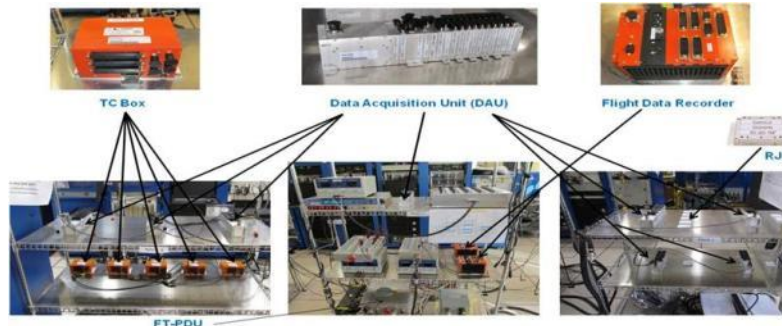
Avionics Components Delivery Continues



Recovery Beacon
GPS Antenna,
Flight Unit
delivered 5/18/12



Integrating the DFI hardware deliveries in the DFI Lab



PDU delivered to the ITL on 5/9/12

- Delivered:

- First EFT-1 Flight Component: Recovery Beacon GPS Antenna
- Remaining EDU DFI Components to DFI Lab
- EDU VPU to VTB-2
- DTA PDU and 3 EDU harness sets to ITL

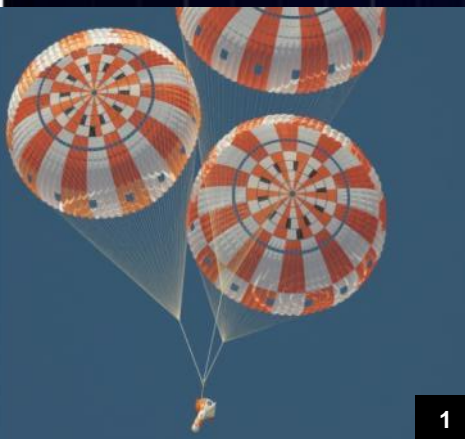


VPU delivery to VTB-2



EDU harnesses delivered to the
ITL, 4/26/12 & 5/8/12

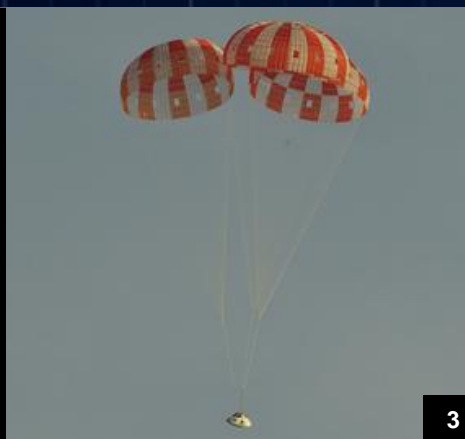
Parachute Drop Test Status



1



2



3



4



5



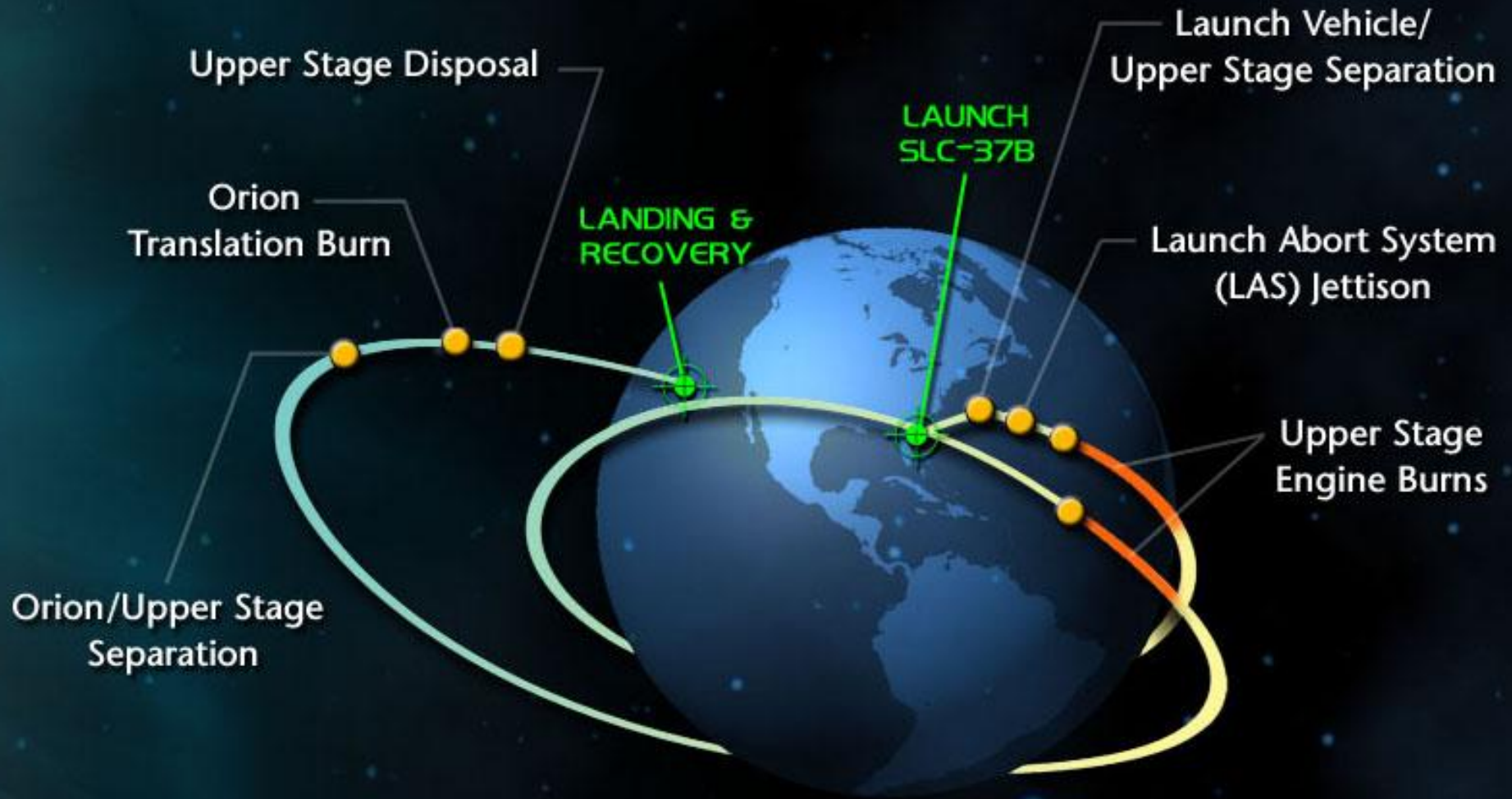
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7

Test	Date	Test Vehicle	Delivery	Low	Alt	Wake	Sys	Test Description	Results
1	9/21/11	PCDTV1	C-130	LOW	NO	FULL		Nominal System	Nominal sequences & deployments. 2 'knuckles' damaged from re-contact
2	12/20/11	PCDTV2	C-130	LOW	NO	MIN		Pilot Fails to Fire (One Main Out)	Nominal sequences & deployments.
3	2/29/12	PTV-1	C-17	LOW	YES	FULL		Nominal System	Nominal sequences & deployments. Significant pitch motion of PTV under drogue parachutes, 2 'knuckles' damaged from re-contact (redesign required)
4	4/17/12	PCDTV3	C-130	LOW	NO	FULL		Skipped 2nd Stage Main	Nominal sequences & deployments. Skipped 2 nd stage chute significantly influenced the delayed opening of the other two chutes, reefing line cutter anomaly, drogue 'knuckle' replacement successful.
5	7/17/12	PTV-2	C-17	LOW	YES	FULL		Skipped Stage (1st Stage Drogue, 2nd Stage Main)	
6	8/28/12	PCDTV4	C-130	LOW	NO	MIN		One Flagging Main Parachute	
7	11/6/12	PTV-3	C-17	LOW	YES	MIN		Drogue and Pilot Fail to Fire	

Exploration Flight Test 1





SLS Overview



SE&I

- Initiated detail Program-to-Program avionics and software integration and verification planning activities
 - Effort focused on exchange of simulation models and emulators in response to SRR/SDR RID's (IAS).
- Conducted Integrated Communications Architecture TIM with SCan, MPCV, MOD, and Air Force Eastern Range

Stages

- SRR/SDR Pre-Board
- SRR/SDR Board

Booster

- Booster IAT meetings at ATK to discuss Basis of Estimates (BOE's) for each WBS. Good discussions with some "holes" identified.
- Booster IAT meeting provided a status of the IAT process and summarized recent changes, Initial Cost Analysis, IMS and BOE summaries.

Engines

- RS-25 Engine Controller CoDR, driving toward early PDR demo in October 12
- Nozzle Jacket improvement VSM Complete
- Powerhead 6013 on the shop floor to begin processing and real time VSM activity

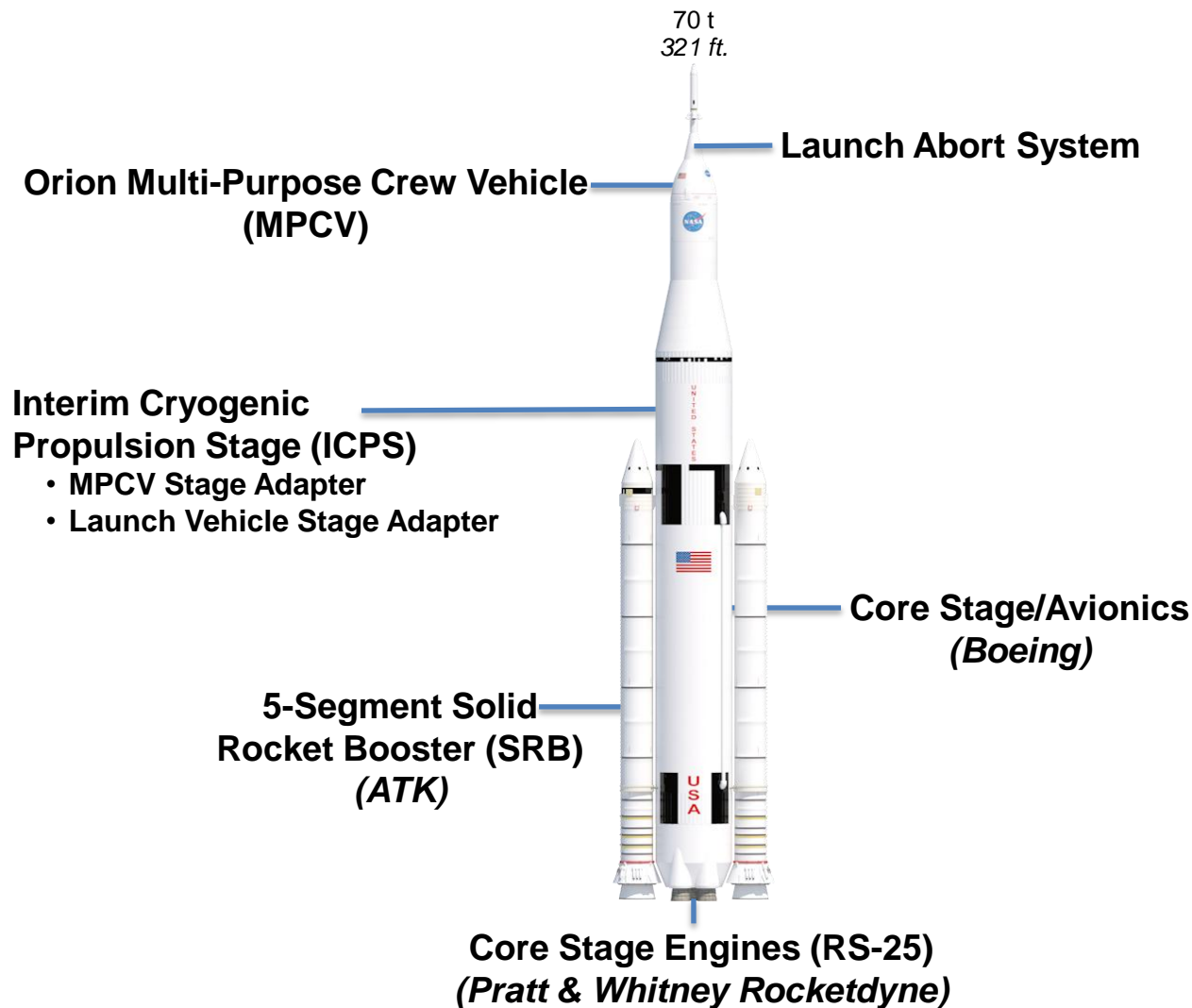
Strategic Planning and Integration Office

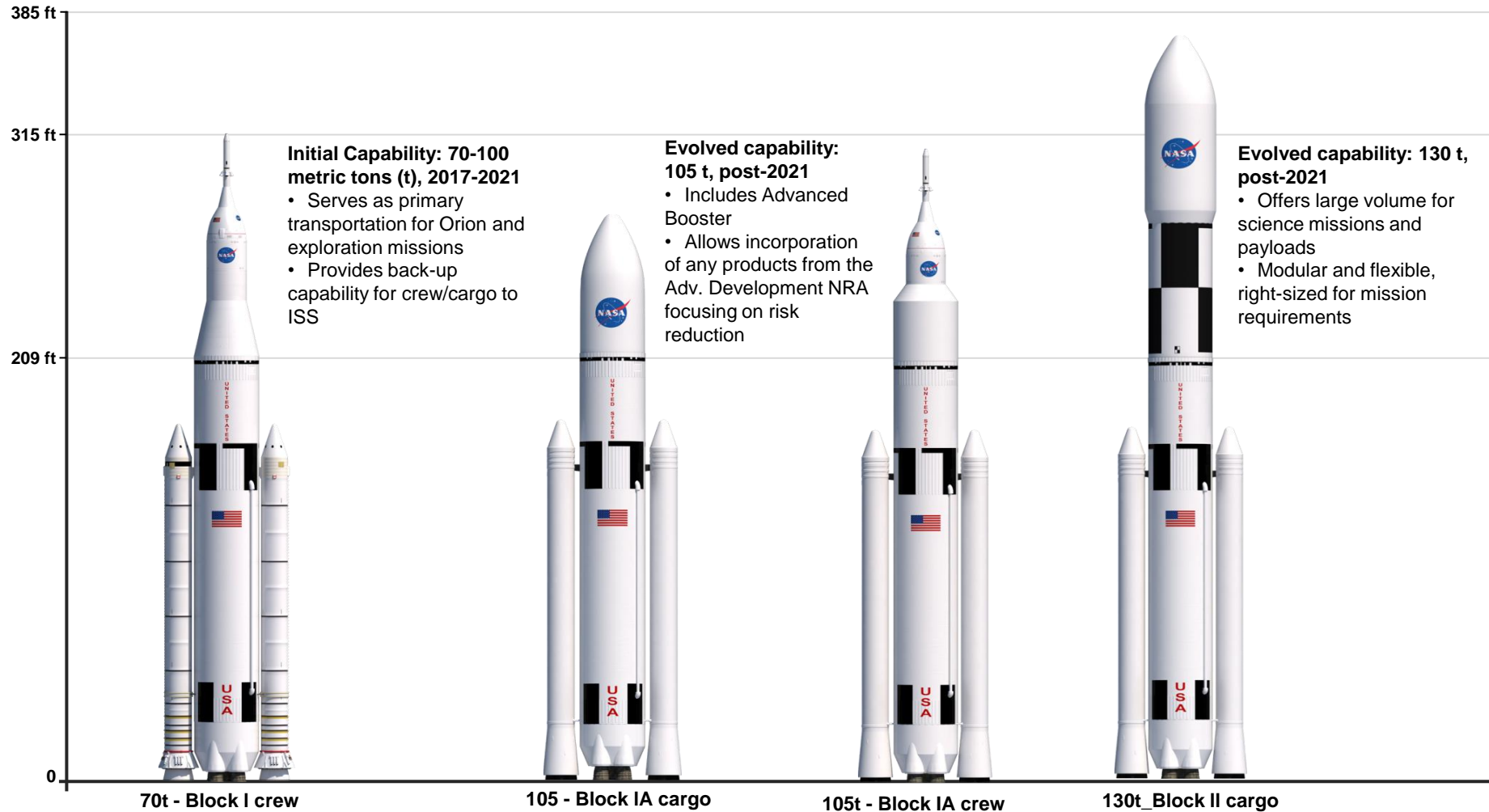
- ICPS Procurement JOFOC comments turned in to MSFC Policy and Legal for review
- Informal safety review for EFT-1 MSA Flight Hazard Analysis conducted
- MSA diaphragm face-to-face meeting conducted at LaRC
- Avionics TIM held between Boeing/ULA/MSFC/JSC
- ICPS Procurement JOFOC synopsis release

SLS 70 Metric Tons: First Flight 2017

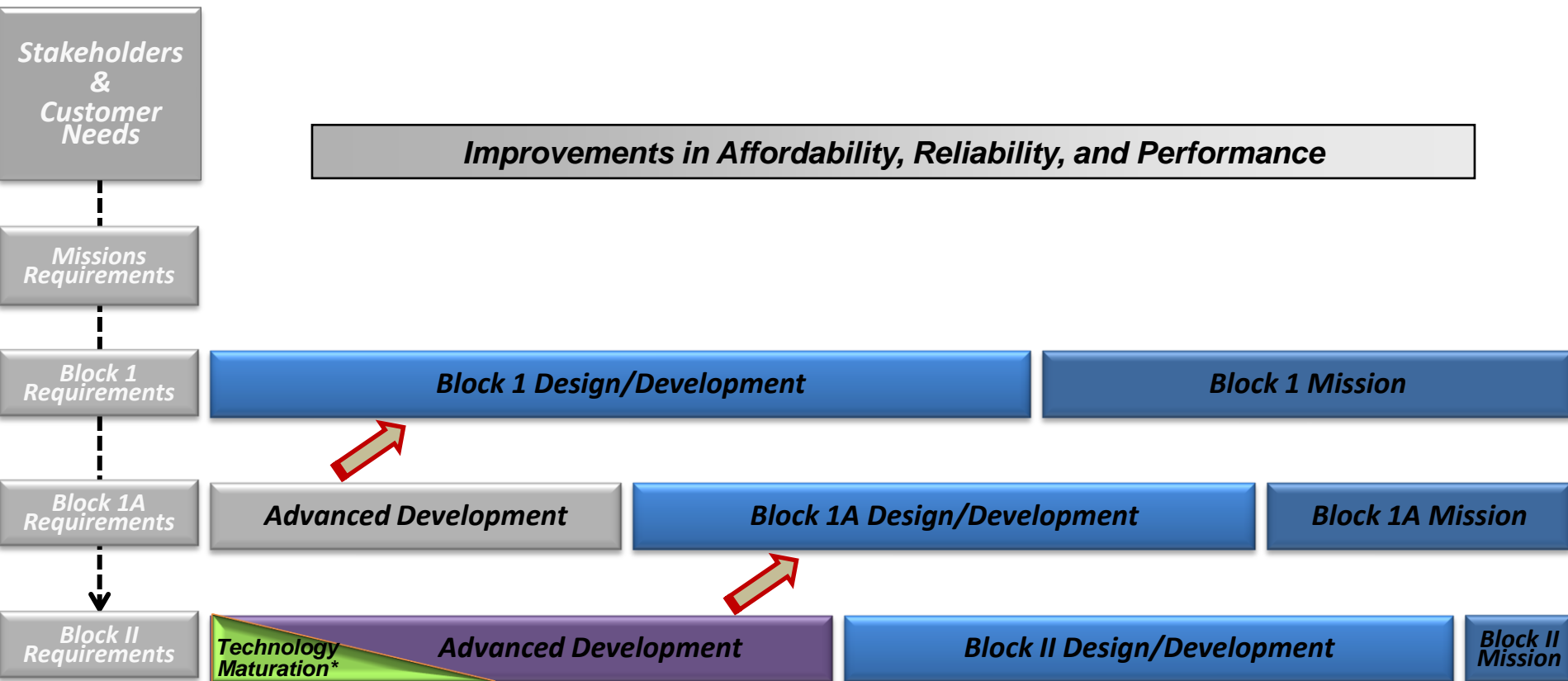


INITIAL CAPABILITY, 2017–21





SLS Philosophy for Evolutionary Upgrades



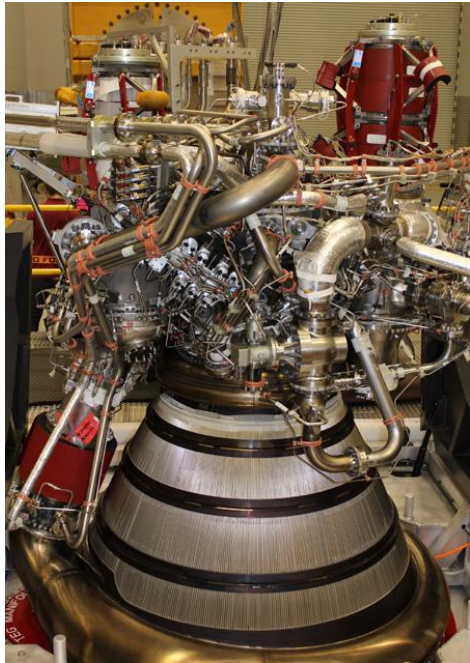
SLS Summary by Element:

Risk Reduction Incorporated in Design



- **Boosters (3-phased approach)**
 - Phase I: 5-segment Solid Rocket Booster in-scope modification to existing Ares contract with ATK for initial flights through 2021
 - Phases II and III: Advanced Boosters
 - II: Engineering demonstration and risk reduction via NASA Research Announcement (NRA): Full and Open Competition in FY12; award by FY13
 - III: Design, Development, Test & Evaluation (DDT&E): Full and Open Competition (RFP target FY15)
- **Stages**
 - Core/Upper Stage: Justification for Other Than Full and Open Competition (JOFOC) to Boeing, modifying current Ares Upper Stage contract
 - Instrument Unit Avionics: In-scope modification to existing Ares contract with Boeing; consolidated with Stages contract to Boeing
- **Engines**
 - Core Stage Engine: 4 RS-25 engines per core; JOFOC to existing Space Shuttle contract with Pratt & Whitney Rocketdyne (PWR)
 - Upper Stage Engine: J-2X in-scope modification to existing Ares contract with PWR
 - Future Core Stage Engine: Separate contract activity to be held in the future
- **Spacecraft and Payload Adapter and Fairing**
 - Initial design: Adapter and Fairing design and development in-house through early design phase
 - Fairing Full and Open Competition planned for FY13

SLS Element Testing



J-2X Testing



Wind Tunnel Testing



Development Motor 3 Firing

SLS: Being Built Today in the U.S.A.



First ring forging prepared for Orion Stage Adapter, Cudahy, WI, April 2012.



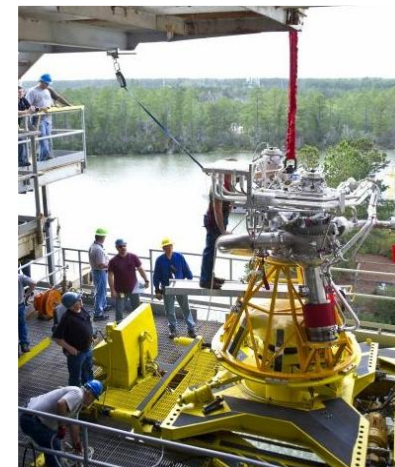
Stages Industry Day at Michoud Assembly Facility, New Orleans, Nov 2011.



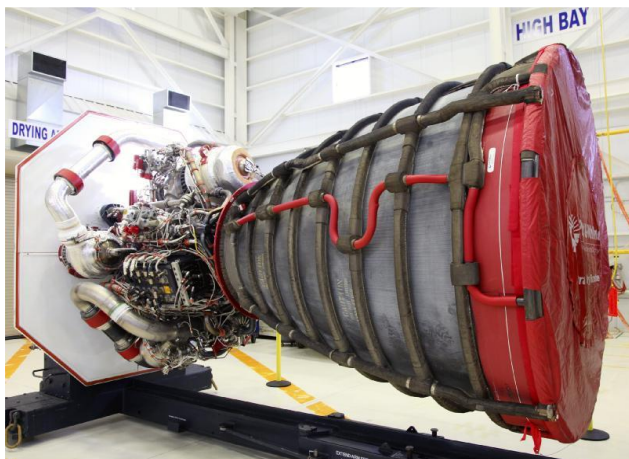
Solid Rocket Booster development motor test, Promontory, Utah, Sep 2011.



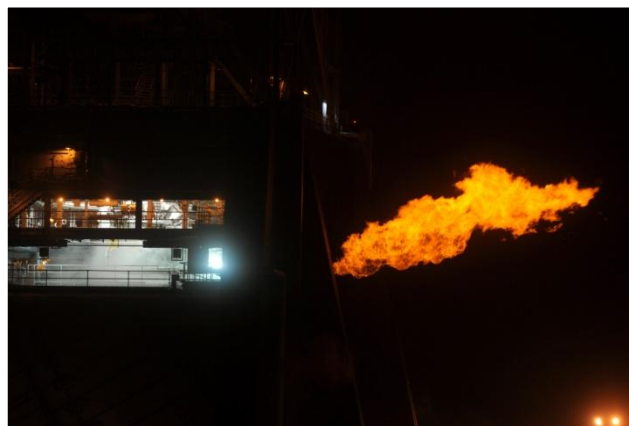
KSC is preparing Launch Complex 39B for SLS/Orion operations, 2012.



Installing the J-2X powerpack in test stand at SSC.



RS-25 Core Stage Engine in the KSC Engine Processing Facility, 2011.



J-2X Upper Stage Engine powerpack test, Stennis Space Center (SSC), MS, Feb 2012.



Meeting with Space Campers at U.S. Space & Rocket Center, Huntsville, AL, Feb 2012.



Ground Systems Development & Operations Status

GSDO Accomplishments



Program

- Architecture Review Cycle 8.0 Architectures Checkpoint Review
- Monthly Program Review
- SRR/SDR kickoff

Vehicle Integration and Launch

- ML Structural Modification Concept review
- High Bay 3 platform demolition contract awarded
- VAB platform design contract awarded
- Crawler-Transporter Jacking/Elevating/Leveling System Awards

Command, Control, Communications and Range

- Initial Phase of Command and Control Technical Assessment Complete
- RESOLVE Science Support operations from FR-1
- Communications at PAD-B are installed and functional. KGCS, KCCS, etc are utilizing basic capabilities and preparing for FR-1 end-to-end first sub-system check-out
- OIS-M Installation Complete for IOZ (EFT-1 Support)
- VAB HB1 & HB3 cable removal design completed and the temporary communication portion of the project is underway with a scheduled completion by end of June 2012

Offline Processing Integration

- Landing & Recovery Stationary Recovery Test Face to Face planning meeting
- EFT-1 CM Delivery to KSC

VAB Accomplishments: 325-Ton Crane



Upgrade 325 Ton Crane, Main and Auxiliary Hooks, Traveling Cable Management Controls for increased Reliability and Robustness. Cranes returned to service.

**Control Cabinets and Motors
Upon Arrival in VAB**



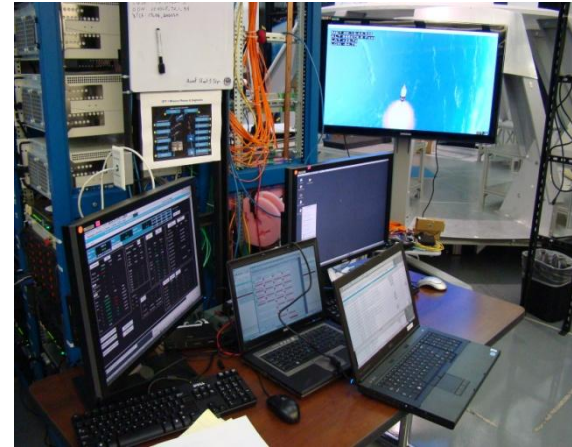
Completed Installation



End-to-End Command & Control Development



Testing telemetry from Orion



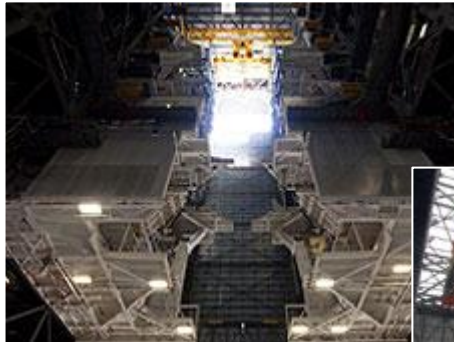
Monitoring launch simulation

Orion Testing rig



Ground Test Article in Crew Module Workstation





NASA's Vehicle Assembly Building is undergoing major renovations so it can support a new generation of rockets and spacecraft.



The 355-foot-tall mobile launcher structure is being modified to support Space Launch System



The Orion ground test vehicle (GTA) is in the Operations and Checkout Facility at KSC



Verification and Validation Approach

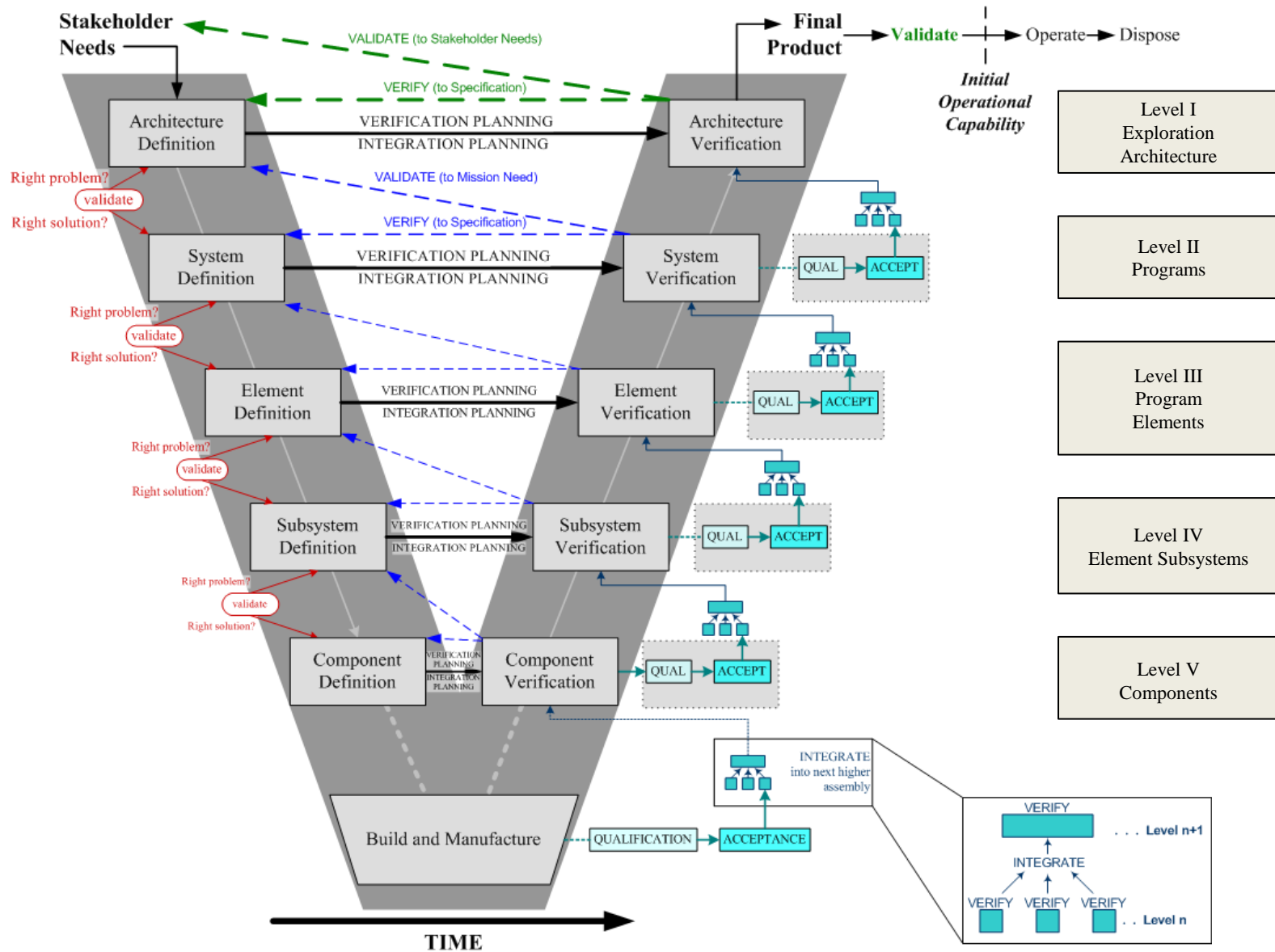
ESD Verification and Validation (V&V) Approach



ESD V&V efforts are conducted per Systems Engineering “V”

- ESD Requirements (17 total), ESD Concept of Operations, and functional analysis form basis of allocated and derived Program SRD Requirements
- Draft V&V methods and objectives identified during requirements development phase
- Programs implement “down and in” V&V of their respective program requirements
 - Integration leadership responsibility allocated to most appropriate Program (e.g.. Lift mass to SLS, Orion control mass to Orion, etc.)
- Verification of cross-program interface requirements delegated to the Programs
 - Each side verifies their side of the interface
 - Both sides concur on the overall verification
 - ESD provides oversight of planning and implementation
- Programs jointly perform incremental integration, assembly, and checkout tests as required to verify and validate interface requirements and integrated performance requirements that cannot be bought-off within individual programs
- Programs define test program, and ESD/Programs jointly define any necessary flight tests
- ESD inspects Programs’ V&V objective evidence to ensure that HEO requirements and ESD Concept of Operations (ConOps) are fulfilled

ESD Verification and Validation (V&V) Approach





- Validation confirms that the end products provide the necessary effectiveness and suitability for use in HEOMD mission operations, per the ESD and Program Concept of Operations documents
- Validation will be conducted via mission analyses/simulations, developmental proof-of-concept tests, element-to-element integrated testing and flight tests of the hardware and software systems as required
 - Programs develop specific validation objectives that need to be accomplished and will jointly develop integrated validation objectives between programs
- Programs are motivated to find areas in the overall V&V flow where both verification and validation objectives can be accomplished with the same method and activity (the same analysis/simulation, test, or demonstration) to reduce cost



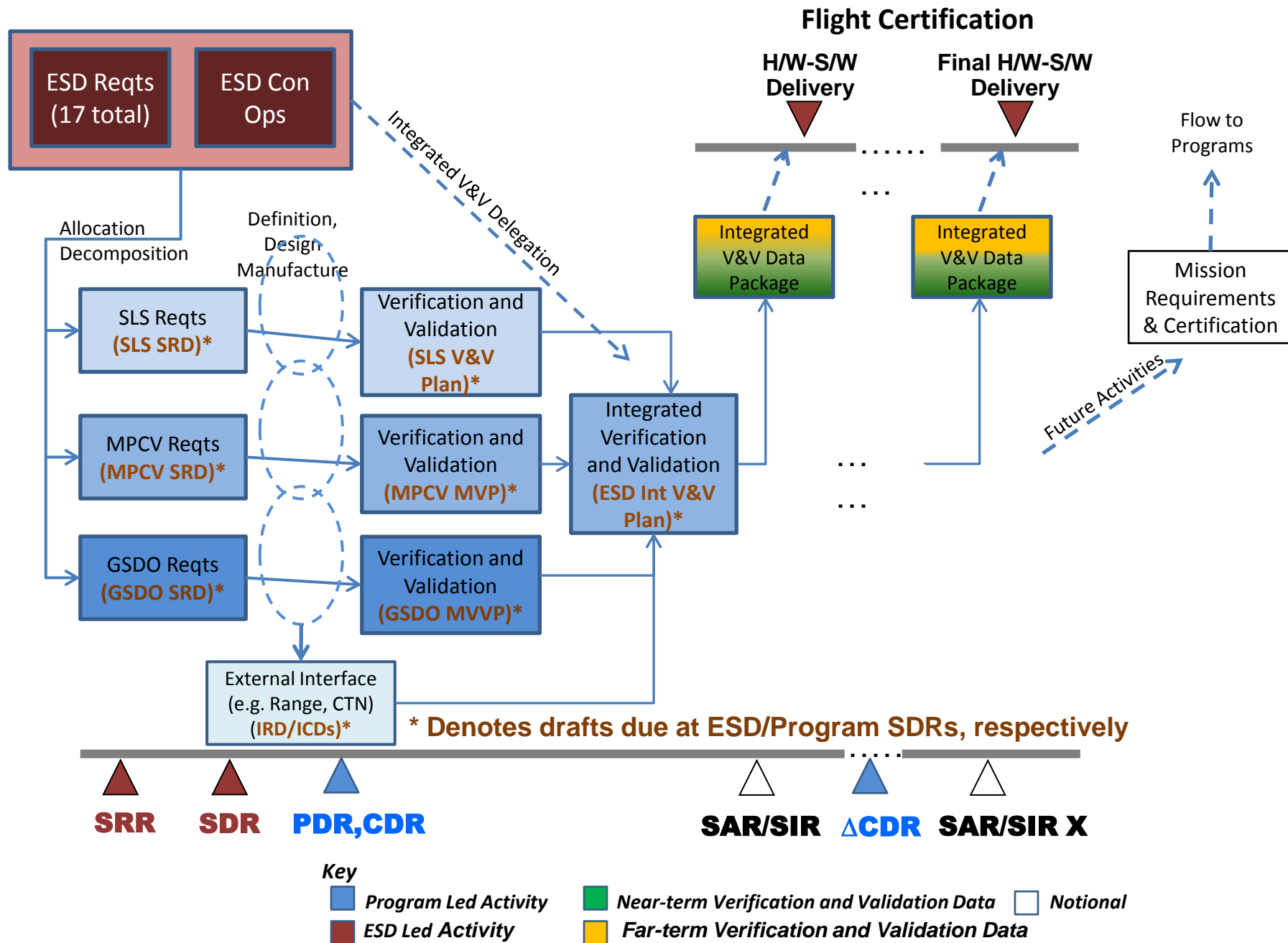
- **Cross Program Integrated V&V Management Approach**
 - ESD HQ and the Programs share integrated V&V responsibilities through a cross-program integration V&V task team that:
 - ensures that cross-program V&V efforts are sufficiently planned and executed during the Programs' lifecycles and is consistent with an integrated V&V strategy
 - clearly identifies, documents and oversees integrated V&V integration expectations and responsibilities across the programs to avoid confusion and integration problems between them
 - facilitates the generation of integrated verification objectives
 - identifies cost and schedule threats/opportunities of integrated tests
- **ESD HQ arbitrates conflicting objectives or objectives that negatively impact mission mass or performance, mission success, cost, schedule and safety.**

ESD Requirements, Program Allocation, and Draft Verification Methods

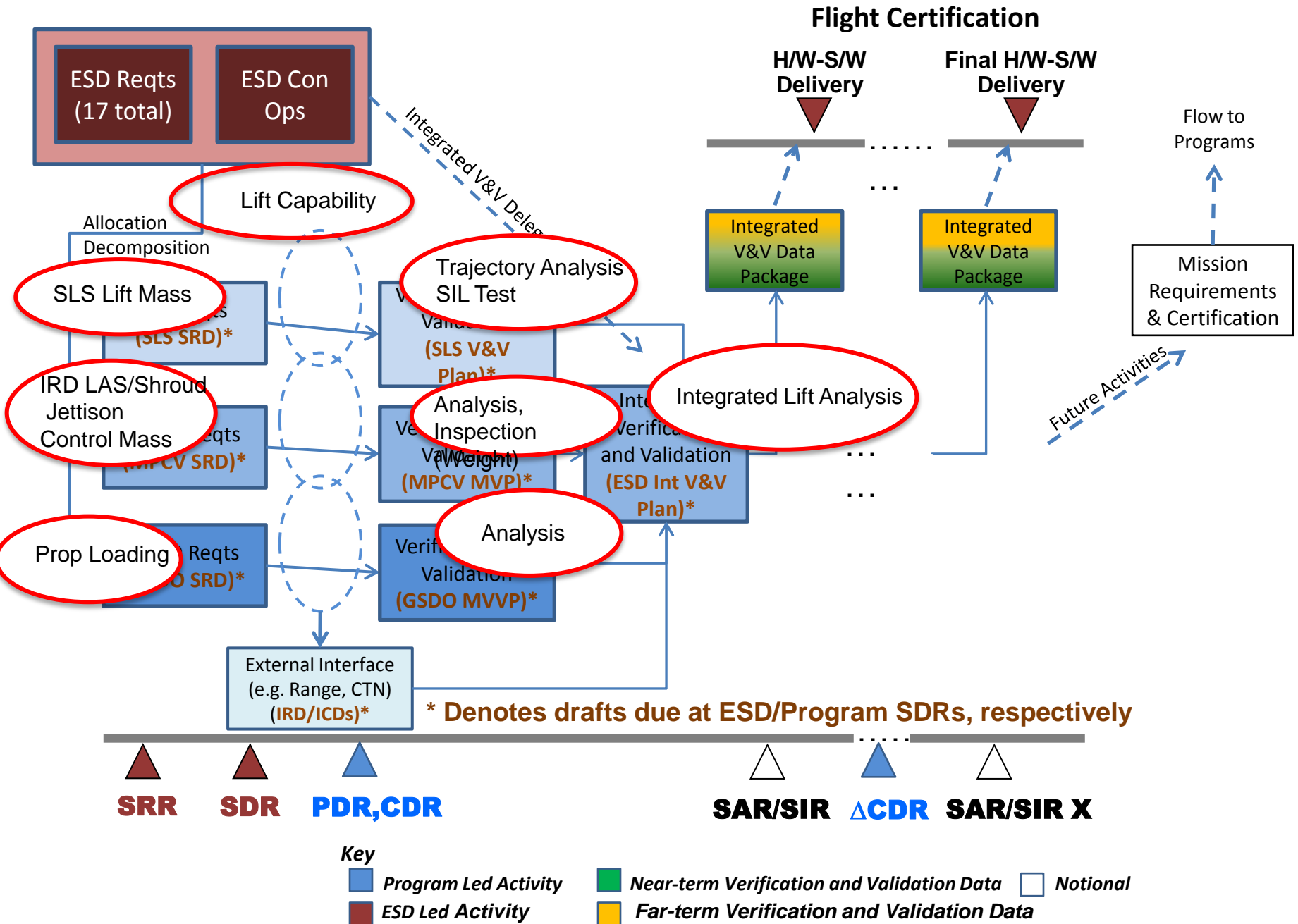


Requirement	<u>DRAFT</u> Verification Method (I,A,D,T)	Program Allocation		
		GSDO	MPCV	SLS
R-1: Earth Entry Velocity	A,I		X	
R-2: Crew Size	A, I	X	X	
R-3: MPCV Delta-V	TBD		X	
R-4: MPCV Active Mission Duration	A, I		X	
R-5: MPCV Control Mass	A, I		X	
R-6: Nominal Post-Landing Crew Recovery	A	X	X	
R-7: Post-Landing Crew Survival	A,I	X	X	
R-8: Cargo Return Mass	A	X	X	
R- 9: Service Module	A		X	
R-10: Human Rating	D	X	X	X
R-11: Lift Capability	A, I	X		X
R-12: Payload Dimensions	TBD	X		X
R-13: Orbital Insertion Accuracy	A			X
R-14: Alternate means of delivering Crew to/from ISS	TBD		X	X
R-15: Launch Rate	A,I	X	X	X
R-16: Loss Of Crew	A		X	X
R-20: Audio and Motion Imagery	I	X	X	X

Near Term V&V Approach Leading Toward Future Capabilities



ESD V&V Notional Example



Capability Driven Framework; Near-term vs. Future capability V&V Approach



- **ESD requirements facilitate a capability driven approach to human exploration (based on CDF) rather than one based on a specific mission destination and schedule**
- **Both near-term and future capabilities of the overall integrated architecture are addressed in the ESD integrated V&V effort**
 - Near-term integrated verification activities/products are linked to applicable near-term deliveries with high-fidelity verification
 - For future capabilities not targeted for near-term flights
 - Assessment/analysis is provided but with lower fidelity
 - Must show clear evolution of near-term to future capabilities
 - Final verification occurs when specific flights/destinations are selected

Mission Capability V&V Approach



- **When a specific mission is selected, a mission team will be assigned to define the overall mission requirements**
- **Overall mission end-to-end integrated V&V efforts will consist of mission-specific incremental V&V (e.g. docking mechanism) in concert with the capability-driven integrated V&V effort**



- **NASA is making excellent progress**
 - Orion has delivered EFT-1 article and continues subsystem testing
 - SLS is proceeding with vehicle design, engine testing, and contract actions
 - Ground Systems is proceeding well with infrastructure refurbishment and multi-user preparations
- **Focused on 2014 and 2017 flight tests**